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September 21, 2000

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APPLICATION NUMBER: *60/152,464*

FILING DATE: *September 03, 1999*

PRIORITY DOCUMENT

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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR A PATENT under 37 CFR 1.53 (b)(2).

Docket Number	14112-6USPR	Type a plus sign (+) inside this box→	+

INVENTOR(s)/APPLICANT(s)

LAST NAME	FIRST NAME	MIDDLE INITIAL	RESIDENCE (CITY AND EITHER STATE OR FOREIGN COUNTRY)
Grudin	Oleg		Montreal, Canada

TITLE OF THE INVENTION *(280 characters max)*

Tube for conversion of gas flow to differential pressure

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ENCLOSED APPLICATION PARTS *(check all that apply)*

X	Specification	*Number of Pages*	3	X	Small Entity Statement
X	Drawings	*Number of Sheets*	8		Other (specify)

METHOD OF PAYMENT *(check one)*

	A check or money order is enclosed to cover the Provisional filing fees		PROVISIONAL FILING FEE AMOUNT ($)	$75.00
X	The Commissioner is hereby authorized to charge filing fees and credit Deposit Account Number:	19-5113		

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

[X] No

[ ] Yes, the name of the U.S. Government agency and the Government contract number are: ______

Respectfully submitted,

SIGNATURE [signature]

Date Sept. 2/99

TYPED or PRINTED NAME James Anglehart

REGISTRATION NO. *(if appropriate)* 38,796

[ ] Additional inventors are being named on separately numbered sheets attached hereto.

PROVISIONAL APPLICATION FILING ONLY

09/03/99 60/152464 09/03/99

In the United States Patent and Trademark Office

"Express Mail" mailing label number: EH576252816US
Date of Deposit: September 3, 1999

I hereby certify that the attached U.S. Patent Application, informal drawings, transmittal letter, verified statement, declaration and power of attorney, information disclosure statement, and application fee are being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to the Assistant Commissioner of Patents, Washington, D.C. 20231.

Randall L. Reed

Randall L. Reed

(Signature)

September 3, 1999

Assistant Commissioner of Patents
Box: Provisional Patent Application
Washington, D.C. 20231

Dear Sir:

Transmitted herewith for filing is the Provisional Patent Application of:

Inventor: Grudin, Oleg
For: Tube for Conversion of Gas Flow to Differential Pressure
Attorney Docket Number: 14112-6USPR

Enclosed are:

1. A Specification with 3 pages.

2. 8 sheets of informal drawings.

3. A Provisional Application for Patent Cover Sheet, signed on September 2, 1999 by James Angelhart Reg. # 38,796. (1 page)

4. A Declaration for Small Entity Status Sheet, signed by Oleg Grudin on September 2,1999. (1 page)

5. A return receipt post card.

Respectfully submitted,

Date: September 3, 1999

Randall L. Reed

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TUBE FOR CONVERSION OF GAS FLOW TO DIFFERENTIAL PRESSURE

Background.
Typically, a gas flowmeter contains a gas flow receiver (GFR), the tube through which gas flow passes and a differential pressure transducer thus connected to the GFR. The transducer measures differential pressure generated by a flow-resistive element placed inside the tube (Fig. 1). For certain applications such as spirometry, a GFR having simple shape, providing easy cleaning and/or disposability, are the most attractive. Among GFRs used in industry and medicine, one can find tubes with flow resistive elements made in the form of plane diaphragms (flow-obstacles designed to create local differential pressure while allowing flow). The closest prototype used in spirometry, is the GFR with crest-like flow resistive element [US Patent 5038773].

The particular design of the GFR used in spirometry is the result of a trade-off between the imperative to increase differential pressure generated by the flow resistive element to obtain higher sensitivity of the flowmeter, and the requirement not to exceed a maximum acceptable back-pressure specified by spirometry standards. For example, American Thoracic Society Standards for Spirometry (1994) requires the back-pressure to be not greater than 150 Pa·s/l in the whole operating range. Therefore the GFR with highest ratio (differential pressure)/(back pressure) is preferable for this particular application.

Another problem to be solved in the described flowmeter is related to reproducibility of transformation characteristic of the GFR that defines flow-to-differential pressure conversion. For this purpose, simpler shapes of the GFR provide easier fabrication, with better reproducibility of the dimensions of the inner surface of the tube, which eventually guarantee reproducibility of the conversion factor. Another result of the tube shape simplification is the reduction of fabrication costs which is of great importance especially for disposable tubes.

One desirable feature for a GFR is insensitivity to the shape of the flux (i.e. gas velocity distribution across the cross-section of the tube) at a GFR input. The importance of this GFR property results from the following considerations. Equipment such as a calibrated syringe or flow bench, used to calibrate the flowmeter, generate flows with gas velocity distribution across the cross-section of the flux determined by the particular shape of their output parts (e.g. narrow versus wide openings; long versus short connections). On the other hand, when the GFR is connected to the investigated flow source (such as a live patient, in spirometry), the gas velocity distribution across the cross-section of the flux cannot be controlled, and can differ substantially from those generated during calibration. Therefore, unpredictable errors in measured flow rate can occur. To reduce sensitivity of the GFR to the flux shape, some changes of the tube are commonly used such as an additional screen on its input, or curving of the tube before the flow resistive element. As a result of these modifications, the generated back-pressure is increased, and shape of the GFR becomes more complex. These can be considered as disadvantages because of the reasons presented above.

The goal of the present invention is to:

- improve (differential pressure)-to-(back pressure) ratio;
- simplify the shape of the GFR for better reproducibility and easier fabrication;
- reduce sensitivity of the GFR to the shape of the flux.

Summary of the invention and description of the drawings

The goal of the invention is solved by the new design of the flow-resistive element of the GFR. The flow-resistive element is made in the form of an obstacle to gas flow having non-symmetrical shape when viewed along the long axis of the GFR tube. The flow-resistive element is designed to simultaneously obtain low overall back-pressure, and high local differential pressure measured between two points inside the GFR. The local differential pressure is created by placing an obstacle in the GFR, directly between the two points inside the GFR at which the differential pressure is measured, as close as possible to the midpoint of the line connecting these two points.

Fig. 1 is a schematic of the GFR (typical prior art).
Fig. 2 is the Gas Flow Receiver with star-like diaphragm (typical prior art).
Fig. 3 is the Gas Flow Receiver with non-symmetrical flow resistive element (this invention).
Fig. 4 shows the measured back-pressure versus flow for both types of the GFRs.
Fig. 5 shows the measured ratio η of differential pressures generated by non-symmetrical and symmetrical flow resistive elements versus flow.
Fig. 6 shows deviations of experimentally measured syringe volume from its actual value obtained during "expiration" and "inspiration", at different averaged flow rates for the GFR with symmetrical star-like obstacle.
Fig. 7 depicts deviations of experimentally-measured syringe volume from its actual value obtained in regimes "expiration" and "inspiration" at different averaged flow for the GFR with invented non-symmetrical flow resistive element.
Fig. 8 is a schematic side view of the GFRs.
Fig. 9 is a schematic front view of the flow resistive element within the GFR tube (viewed along the long axis of the tube).

Description of the preferred embodiment

To prove the invented idea, two experimental GFRs have been constructed. Each of the star-like symmetrical diaphragm and the invented non-symmetrical diaphragm were placed in the middle of identical tubes 120mm long with input inner diameter of 21mm and inner diameter of 19mm at the center of the tube (Figs.2 and 3). The shapes of the flow resistive elements have been chosen so as to generate back pressure lower then 150Pa·s/l (required by ATS standards for spirometry). The six beams of the star-like diaphragm have width of 1mm each. The central spot of the diaphragm has a diameter of 4mm. The non-symmetrical diaphragm has the shape of a circular segment with height of 4mm. The star-like diaphragm has thickness of 1mm while segment-type diaphragm has a thickness of 0.1-0.2mm.

Each of the GFRs was connected to the same differential pressure transducer and individually calibrated. Back pressure was measured by an additional pressure sensor. 3-liter calibration syringe "SpiroCal" fabricated by Burdick Inc. (Milton, WI, USA) was used to generate gas flows during the experiments. Fig. 4 shows dependence of back pressure versus air flow for two GFRs. Fig. 5 depicts ratio $\eta=\Delta P_1/\Delta P_2$ as function of flow, where ΔP_1 and ΔP_2 are differential pressures generated by the GFRs with the invented non-symmetrical diaphragm, and symmetrical star-like diaphragm respectively. The invented GFR generates lower back pressure and higher differential pressure then the GFR with symmetrical diaphragm.

To check sensitivity of two tubes to gas velocity distribution across the cross-section of the tube, the following two-step experiment was performed. In the first step, each tube (after calibration)

was connected to the syringe and gas was "inspired" from ambient through the tube into the syringe by piston strokes at different flow rates – "inspiration". The inspired volume was measured by the electronic module combined with special software package, and compared with the actual volume of the syringe. In the second step, each tube was rotated by 180 degrees, such that its flow direction was reversed, and connected to the syringe with its opposite end, and the same experiments were conducted except with gas being pumped out of the syringe, by "expiration" piston strokes. Thus, the direction of gas flow in the tubes was the same, but the connections, and thus, the gas flow velocity distributions in the flux, were different. In the first step, the GFR input is connected directly to an infinite volume of ambient gas, while in the second step the gas flux entering the GFR is shaped by a 40mm-long connecting tube with inner diameter of 30mm. Deviations (in %) of experimentally measured syringe volume from its actual value, obtained in the regimes "expiration" and "inspiration" at different averaged flows, for the two tested GFRs, are presented in Figs. 6 and 7. The GFR with the star-like diaphragm demonstrated a discrepancy in measured volumes up to 8.5% due to changes of its orientation, which confirms its sensitivity to gas velocity distribution across the cross-section of the tube. For the invented tube, these discrepancies did not exceed 1%, which demonstrates substantially lower sensitivity to gas velocity distribution across the cross-section of the flux.

The invented GFR has a simpler shape than the GFR with symmetrical star-like diaphragm or crest-type flow resistive element, which can simplify its fabrication and improve reproducibility of the conversion characteristic.

The described embodiment confirms the advantages of the invented solution. Meanwhile other shapes of non-symmetrical flow resistive element can be used for the claimed purposes. The GFRs containing the invented flow-resistive elements in the form of non-symmetrical circular segments with heights of 3mm and 5mm, have been also tested. Experimental results are presented in Figs. 4 and 5 by triangles and circles. These variations have also demonstrated low sensitivity to gas velocity distribution across the cross-section of the flux.

Increase of the thickness of the circular segment obstacle from 0.2 to 1-2mm does not cause significant changes in the conversion characteristics of the GFR. Observed deviations of back-pressure and local differential pressure did not exceed 5%.

Figs. 8 and 9 show several possible designs of the GFR that do not exhaust all possible shapes of the GFRs. Particular choice of certain GFR should provide optimal adaptation to the given application and fabrication process technology.

Applicant or Patentee: Oleg Grudin
Application or Patent No.: ______ Atty. Dkt. No.: 14112-6USPR
Filed or Issued: herewith
Title: "Tube for conversion of gas flow to differential pressure"

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS [(37 CFR 1.9(f) and 1.27 (b)] - INDEPENDENT INVENTOR

As a below named inventor, I hereby declare that I qualify as an independent inventor as defined in 37 CFR 1.9(c) for purposes of paying reduced fees to the Patent and Trademark Office described in:

- [x] the specification filed herewith with title as listed above.
- [ ] the application identified above.
- [ ] the patent identified above.

I have not assigned, granted, conveyed or licensed and am under no obligation under contract or law to assign, grant, convey or license, any rights in the invention to any person who would not qualify as an independent inventor under 37 CFR 1.9(c) if that person had made the invention, or to any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

Each person, concern or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention is listed below:

- [x] No such person, concern, or organization exists.
- [ ] Each such person, concern, or organization is listed below.

FULL NAME ______
ADDRESS ______
( ) INDIVIDUAL ( ) SMALL BUSINESS CONCERN ( ) NONPROFIT ORGANIZATION

FULL NAME ______
ADDRESS ______
( ) INDIVIDUAL ( ) SMALL BUSINESS CONCERN ( ) NONPROFIT ORGANIZATION

Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. [37 CFR 1.27]

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. [37 CFR 1.28(b)]

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

NAME OF INVENTOR	SIGNATURE OF INVENTOR	DATE
Oleg Grudin	[signature]	02. Sept 1999

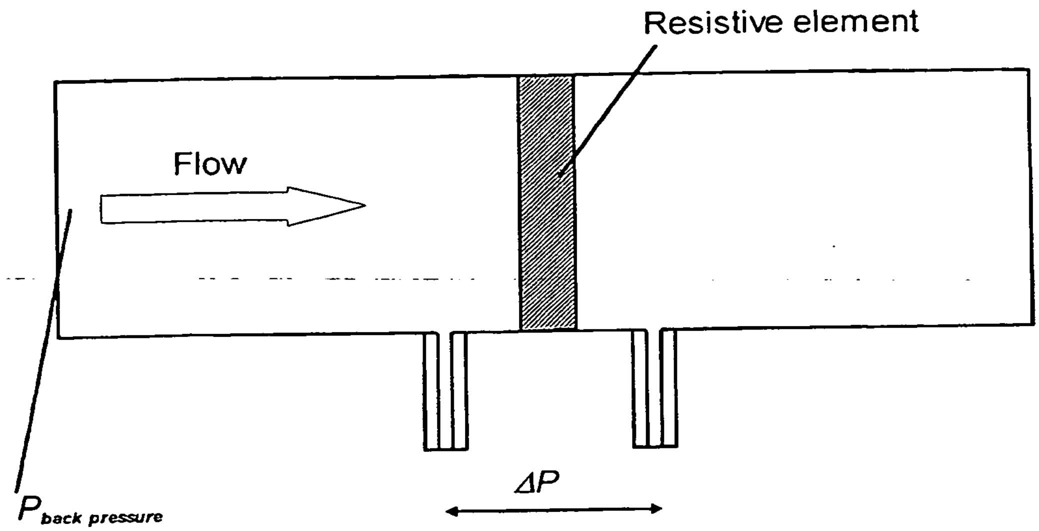


Fig. 1

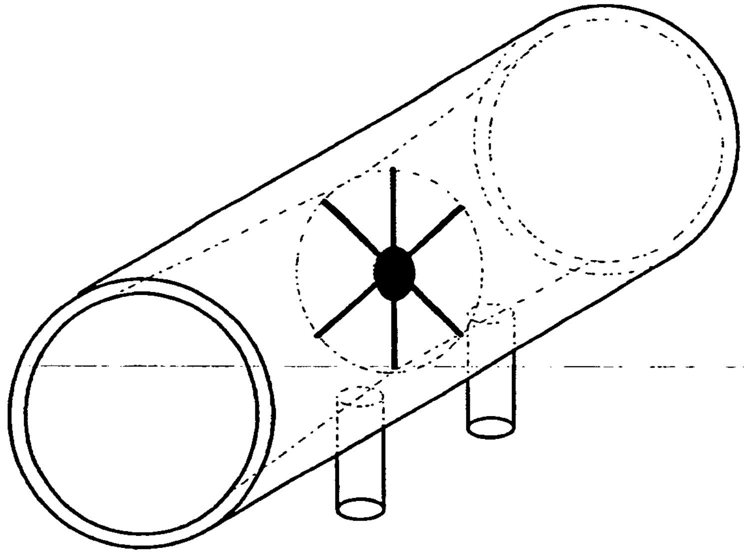


Fig. 2

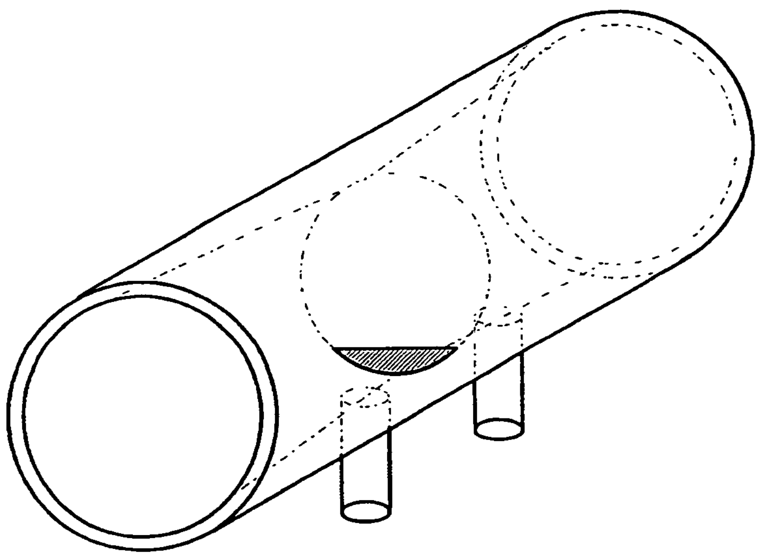


Fig. 3

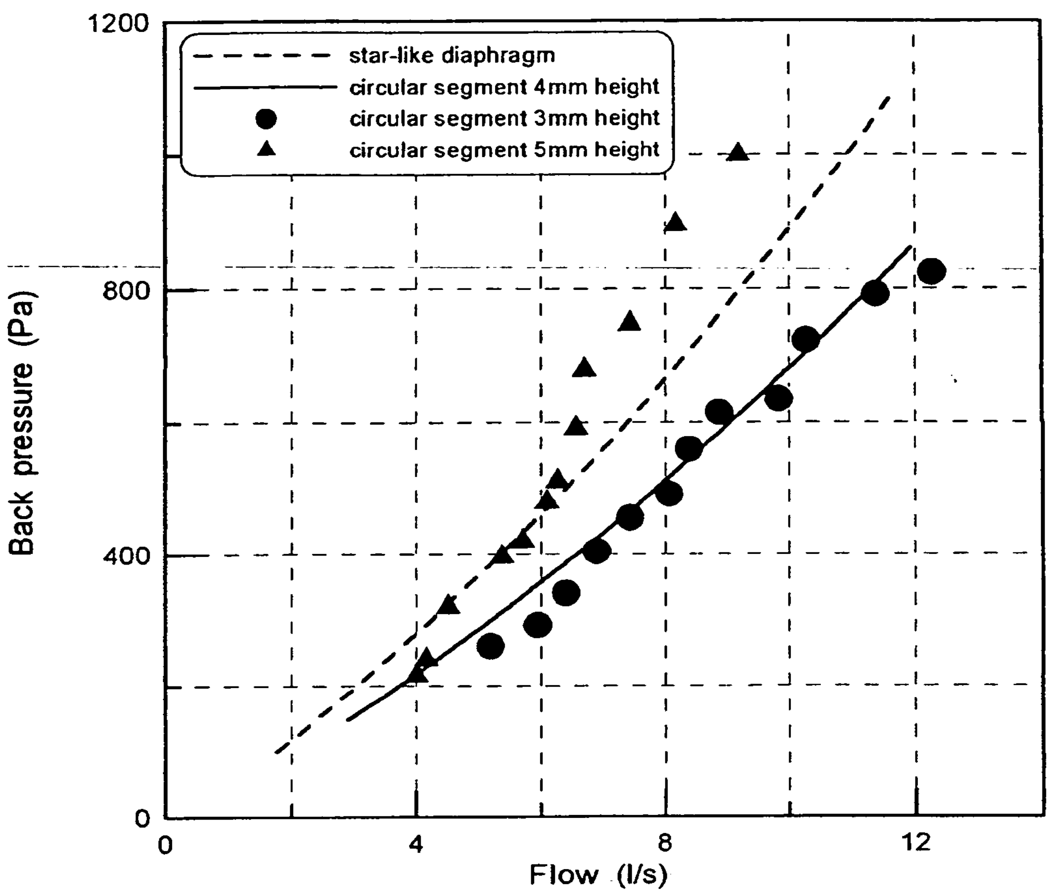

star-like diaphragm
circular segment 4mm height
circular segment 3mm height
circular segment 5mm height
1200
800
400
0
Back pressure (Pa)
0
4
8
12
Flow (l/s)

Fig. 4

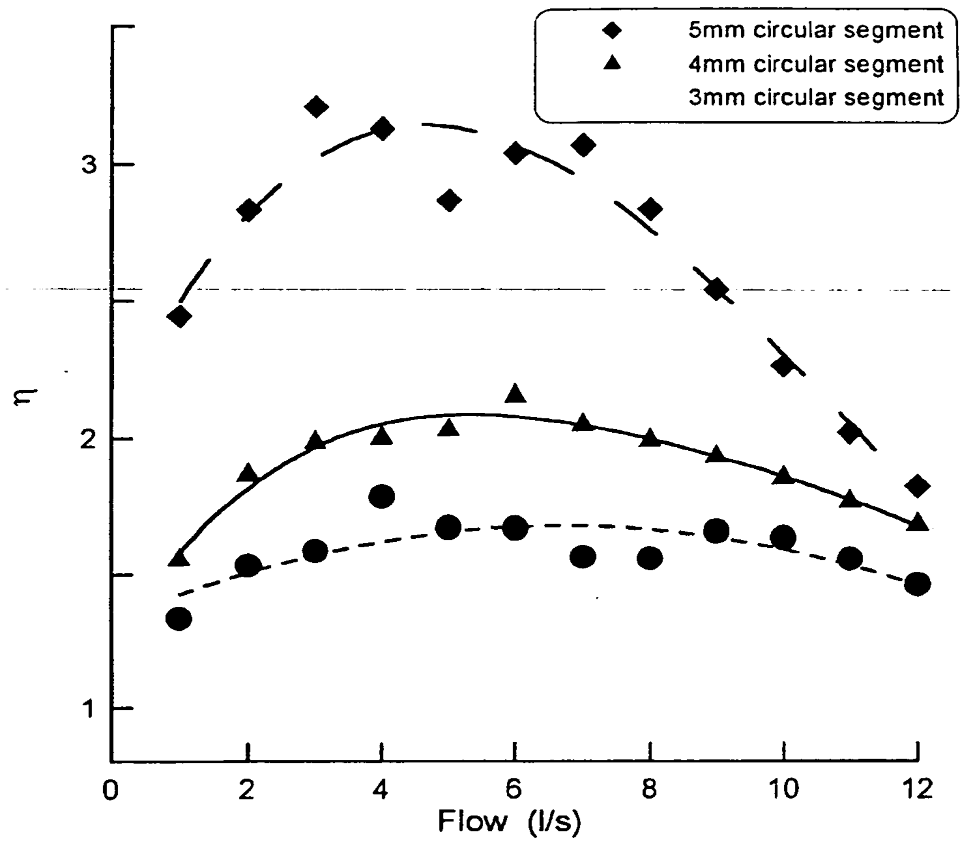
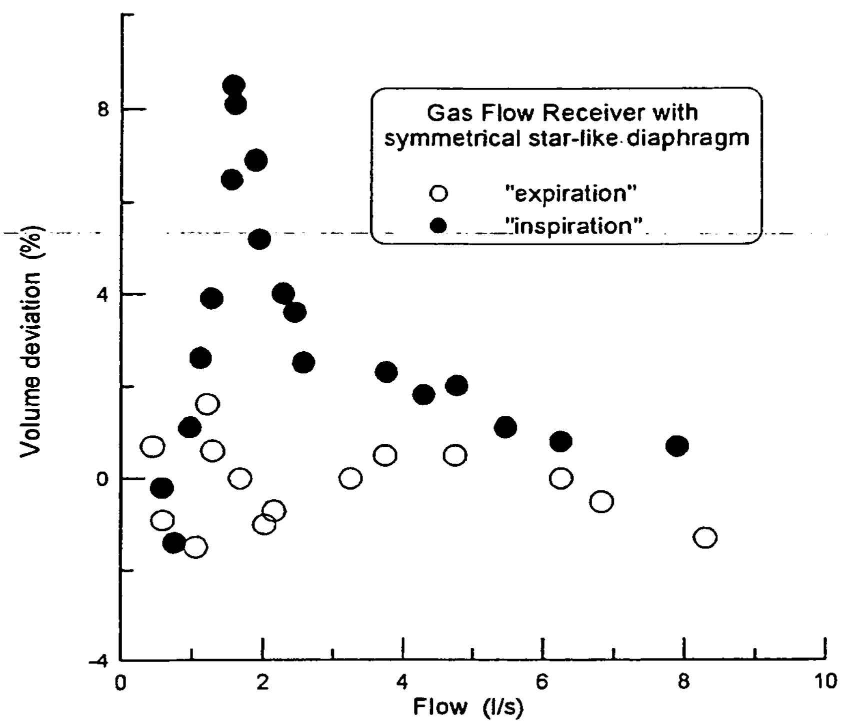

5mm circular segment
4mm circular segment
3mm circular segment
η
3
2
1
0
2
4
6
8
10
12
Flow (l/s)

Fig. 5



Gas Flow Receiver with
symmetrical star-like diaphragm
"expiration"
"inspiration"
Volume deviation (%)
Flow (l/s)
8
4
0
-4
0
2
4
6
8
10

Fig. 6.

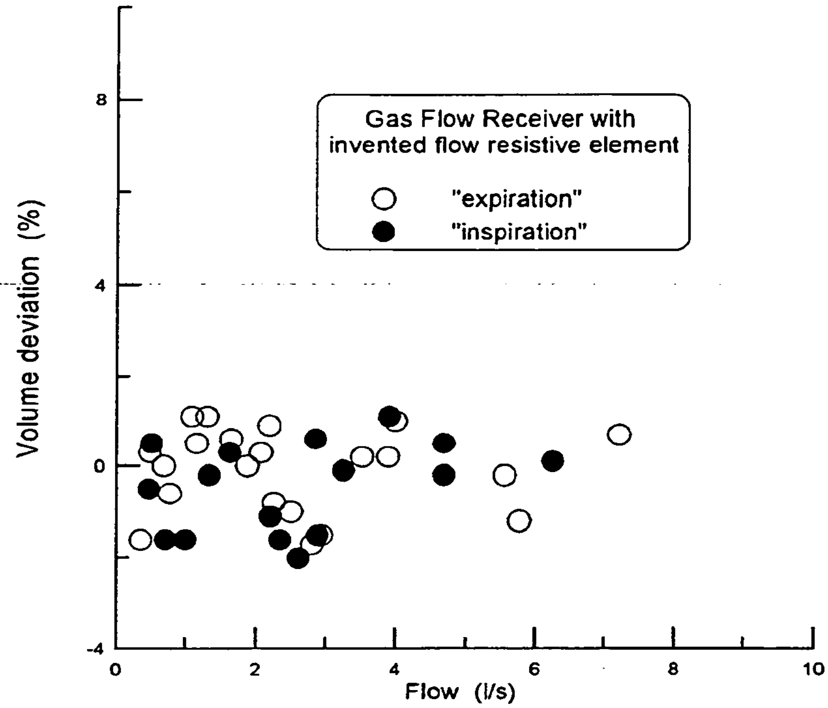

Gas Flow Receiver with
invented flow resistive element
"expiration"
"inspiration"
Volume deviation (%)
Flow (l/s)
8
4
0
-4
0
2
4
6
8
10

Fig. 7.

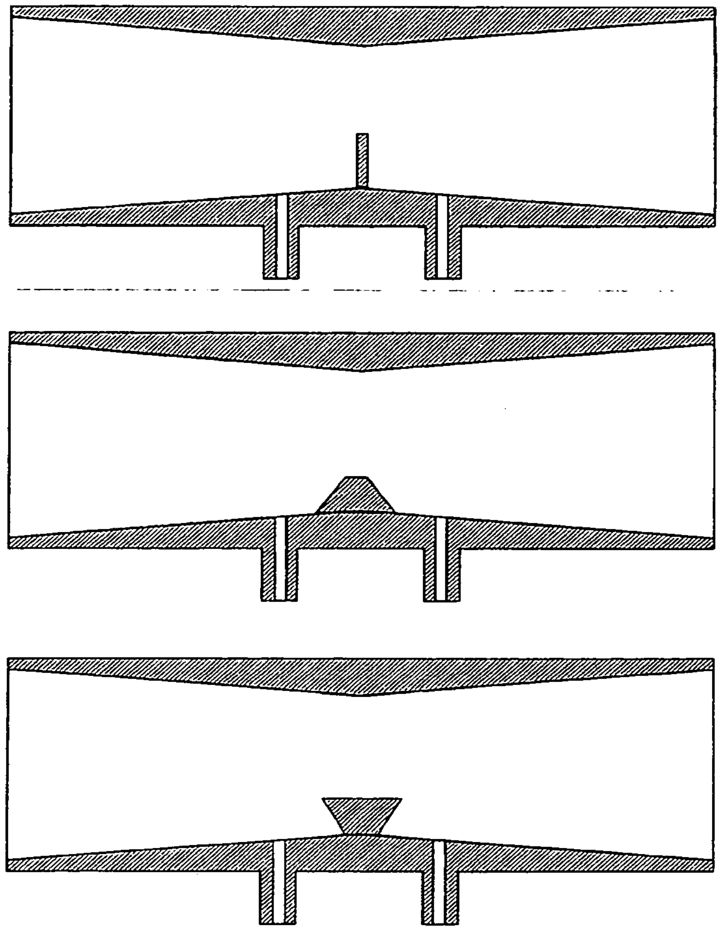


Fig. 8

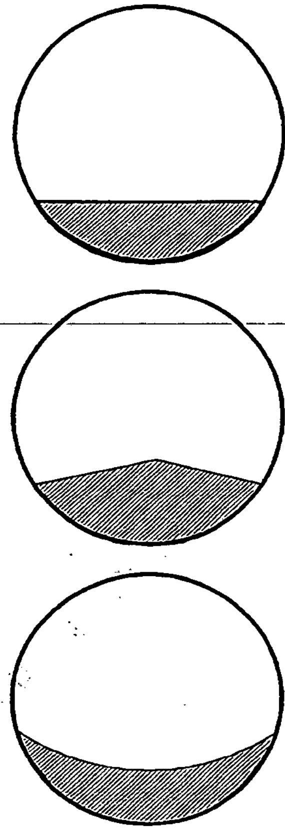


Fig. 9